

# Assessment of Periwinkle Shells Ash as Composite Materials for Particle Board Production

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**Abstract—** Composites based on natural fibre reinforcement have generated wide research and engineering interest in the last few decades due to their low density, high strength, low cost, renewability, and biodegradability. In this work, periwinkle shell ash reinforced polyethylene composite was developed under variation of the filler weight (5, 10, 15 and 20) %wt using compression moulding method. Composite of various compositions were developed and their properties evaluated with a view to assess its suitability for particle board production. The periwinkle shell was sourced locally and the polyethylene was also locally obtained from waste pure water sachet. The water absorption, thickness swelling, density, modulus of rupture (MOR), modulus of elasticity (MOE), ultimate tensile Strength (UTS), tensile modulus (E) and percentage elongation (El) were determined. The results showed high MOR of 25.80 MPa, MOE of 108.80 MPa, UTS of 9.32 MPa, and E of 25.90 MPa and El of 63.39 % for periwinkle shell ash polyethylene composite. The least water absorption is 22 % while the least thickness swelling is 6 %. The results obtained meet the minimum standard requirement for particle board production.

**Index Terms—** Composite, Periwinkle shell ash, polyethylene, Particle board, strength.

## I. INTRODUCTION

The demand for wood as a raw material in the forest industry has been on the increase, and the production of industrial wood from the natural forests cannot meet the demand as such leading to the continuous decline of wood production. The reduction in forest resources in developing countries is as a result of the depletion of the resources. However the decline in developed countries may be due to the withdrawal of forest areas for industrial production and for other uses such as recreational areas. In addition, there is a significant pressure on standing forest resources as a result of higher demand for wood due to the increasing population and new application areas. Consequently, there is a need for alternative resources to substitute wood as raw material [1].

## B. Composite Materials

Most present day engineering materials are expected to be light weight, corrosion resistant, and have high strength, and since no material in nature possesses all these properties, alloys and composites have been developed. Whereas alloys consist of two or more materials formed by metallurgical process, composites are engineered materials made from two or more constituent materials with significantly different properties. The components of a composite can be metals only or metal in combination with non-metals like polymers or non-metals only [2].

## C. Periwinkle Shell

Periwinkle is a waste product got from the consumption of small marine snail (periwinkle) which is housed in a v-shaped spiral shell and is found in many coastal communities in Nigeria. It is also available in many coastal areas worldwide and is very strong, hard and brittle material. Stretching from the Niger Delta between Calabar in the East and Badagry in the Western part of Nigeria, the people in these areas take the edible part as sea food and dispose of the shell as waste product, though a few persons use the shell as coarse aggregate in concrete in places where there are neither stones nor granite for such purposes [3]. There are however, large amount of these shells being disposed of as waste thus constituting environmental problems in places where use cannot be found for them.

## D. Pure Water Sachet

Pure water sachet is a low-density polythene which is heavily characterized by hydrocarbon chains (just as the bitumen) resulting to a tough material insoluble at room temperature, but does at high temperature in the presence of aromatic hydrocarbons [4]. Other research works have also classified pure water sachet as low density polythene [5] and [6].

The heavy burden of deforestation and regeneration created the decrease in available supplies of solid wood in the production of particleboard gave birth to the idea of recycling agricultural waste product [7]. The deforestation is becoming high making the vegetative

cover so low which affect communities and cause environmental degradation. Also, the rampant disposal of periwinkle shells in the southern part of Nigeria serves as environmental pollution. On the other hand the indiscriminate disposal of low density polyethylene has continued to constitute environmental damage to the surroundings. Even where these wastes are burnt, they still result in global warming which is affecting the environment negatively. These materials are all day-to-day wastes release to the environment continuously as commercial activities involving them increase in the country. Thus making use of these agricultural wastes along with recycling used polyethylene pure water sachet will reduce the rate of environmental degradation. As these wastes are turned into useful materials, they may support the achievement of a cleaner, safer and an eco-friendly environment.

The main aim of this work is to develop and assess the properties of periwinkle shell – plastic composite for particle board production. The reinforcement of the composite is periwinkle shell ash while the matrix is a recycled polyethylene from pure water sachets

## II. MATERIALS AND METHODS

### A. Materials

The materials and equipment used in the various tests carried out are presented in this section. The materials and equipment used for the preparation of the recycled low density polyethylene are water, basin, scissors, and razor blades.

### B. Methods

#### Low Density Polythene Processing

Empty water sachets were gathered from Mando community of Igabi Local Government Area in Kaduna State of Nigeria. They were then washed, dried and cut into small pieces using scissors or blades for ease of compounding.

#### Periwinkle Shell Processing

Periwinkle shell ash was used for this research work. Fresh periwinkle shells were obtained from Sheik Gumi Central Market, Kaduna. They were washed and dried. Periwinkle shells were heated in a furnace to a temperature of 850 °C, where they were turned into their carbon ash. This was done in order to reduce their hydrophilic properties and the percentage composition of moisture [8].

#### Processing of the Composites

Periwinkle shell ash particulate of 150µm was used to reinforce low density polythene, which served as the matrix [5] and [9]. Formulation of the compositions was based on the information obtained from the pre analysis carried out on the reinforcement (Table 1).

Table 1: Composite Formulation [10]

S/N	PWK (wt%)	PE (wt%)
1	5	95
2	10	90
3	15	85
4	20	80

Where PE stands for Polyethylene water sachet and PWK stands for Periwinkle shell.

### Sieve Analysis of the Reinforcement

This was done in order to separate the unwanted elements that may have mixed with the particulate and also for characterizing the particle size using a mesh. The particle was sieved using 150µm sieve in accordance with ASTM D 192-01 to have finer particle size [11].

### Elemental Composition of Periwinkle Particulates

XRF test was carried out on X-ray spectrometer, designed for elemental analysis of wide range of samples. The machine makes use of PW 4030 X-ray Spectrometer, which is an energy dispersion, microprocessor controlled, analytical instrument, designed for detection and measurement of elements in sample ranging from sodium to uranium.

The sample, being in powdered form, was weighed and a binder (PVC dissolved in Toluene) was added to the sample, which was carefully mixed and pressed in hydraulic press into a pellet.

The pellet was loaded in the sample chamber of the spectrometer then, voltage (300 kV maximum) and a current (1mA maximum) was applied to produce X-ray, which excited the sample for 15mins. The spectrum from the sample was analyzed to determine the percentage composition of the elements in the sample.

### Compounding

This was done when all the materials were measured as specified for each composition then compounded together to form the composite (table 2). After drying in an oven at 105 °C, the periwinkle Particulate ash and the polythene were compounded in a two roll mill at a temperature of 150 °C into a homogenous mixture [12].

### Pressing

The composites after been compounded were pressed to increase their compatibility. This was carried out on an electrically heated hydraulic press. The compounded mixture were placed in a square mould of length 150 mm and pressed with a pressure of 0.4 MN/m<sup>2</sup> until they cured. The temperature of the plate was maintained at 150 °C during the pressing. At the end of press cycle, the board was removed from the pressing machine for cooling and then cut into specimens for characterization [13].

### C. Physical Properties

#### Density

The basic method of determining the density of board composite samples is by measuring the mass and the volume of the sample used. Each composite was weighed using laboratory weighing balance while the volume was calculated by multiplying the length by the breath by the height of the sample. The density was calculated using equation 1 ( $length \times breath \times height$ ) (ASTM D 792).



$$\text{Density} = \frac{\text{mass}}{\text{vol}} \quad (1)$$

#### Water Absorption (WA) and Thickness Swelling Properties

Specimens with dimensions of 50 mm x 50 mm were prepared for evaluation of water absorption and thickness swelling. The composite samples were immersed in water at room temperature for 24 hours. Samples were weighed and the weight of the samples was determined before immersion in water and after removing from water. After the samples were removed, they were gently clean with soft cloth to remove excess of water and then weighed and recorded. The water absorption was calculated using equation 2 (BSI, 2003), ASTM D570 and [5] Idris et al, 2011.

$$\text{Water absorption (WA)} = \frac{W_n - W_d}{W_d} \times 100 \quad (2)$$

Where:  $W_n$  is the weight of composite after immersion,  
 $W_d$  is the weight of the composite before immersion.

#### Thickness swelling

The thickness at the middle of the test was measured with a micrometer before and after immersion. Thickness swelling (TS) was determined using equation 3. BSI, 2003 and [5].

$$\text{Thickness swelling (TS)} = \frac{T_i - T_o}{T_o} \times 100 \quad (3)$$

Where:  $T_i$  is the thickness of the composite after 24 hr immersion and  $T_o$  is the thickness of the composite before immersion.

#### D. Mechanical Properties

##### Modulus of Rupture (MOR)

The test specimens of dimensions 125 mm x 12.7 mm x 3.2 mm were subjected to a load on the Universal testing machine with the support span length of 40 mm at a speed of 10 mm/min. The specimens were supported at each end and loaded at the center. The forward movement of the machine leads to gradual increase of load at the middle span until failure of the test specimen occurred. At the point of failure, the force exerted on the specimen that caused the failure was recorded (ASTM D790). The modulus of rupture (MOR) of the test specimens were calculated using equation 4 [6].

$$\text{MOR} = \frac{3PL}{2bd^2} \quad (4)$$

Where:  $P$  is the breaking load,  $L$  is the span Length,  $b$  is the sample breath and  $d$  is the sample depth.

##### Modulus of Elasticity (MOE)

The Composite stiffness (MOE) was obtained using equation 5 [6].

$$\text{MOE} = \frac{l^3 m}{4bd^3} \quad (5)$$

Where:  $L$  is the span length,  $m$  is the gradient (i.e slope) of the initial straight-line portion of the load – deflection graph,  $b$  is the width of the specimen and  $d$  is the thickness of the specimen or depth.

##### Ultimate Tensile strength (UTS)

The test specimens were cut into dumbbell shape of dimension 120 mm x 15 mm x 4 mm and the composite was subjected to a load on a Universal testing machine. The specimens were hooked up at both ends of gauge length 40mm with a speed of 5mm/min. The movement of the hook leads to gradual increase of the load at the middle span until failure of the test specimen occurred (ASTM D638). The ultimate tensile strength of the specimen was calculated using equation 6.

$$\text{UTS} = \frac{P}{bd} \quad (6)$$

Where:  $P$  is the breaking load,  $b$  is the original width of the specimen, and  $d$  is the original thickness of the specimen.

##### Tensile (Young) Modulus (E)

The Composite's young modulus was determined from the tensile test performed on each specimen and it was calculated using equation 7.

$$\text{Young modulus (E)} = \frac{\text{Stress}}{\text{Strain}} \quad (7)$$

##### Percentage Elongation (El)

The Composite's percentage elongation was evaluated using equation 8.

$$\text{Percentage elongation (El)} = \frac{E}{L} \times 100 \quad \dots \quad (8)$$

Where:  $E$  is the elongation at failure and  $L$  is the initial gauge length.

### III. RESULTS AND DISCUSSION

The results obtained from the various experiments conducted are presented in this section. Also presented here are the discussions on the results obtained.

#### A. Results

The chemical composition of the periwinkle shell (PWK) is shown in table 2 and fig 1.

Table 2: Chemical composition of periwinkle shell ash

Constituents	Amount present in PWK (wt %)
SiO <sub>2</sub>	-
Al <sub>2</sub> O <sub>3</sub>	0.50
Fe <sub>2</sub> O <sub>3</sub>	2.06
CaO	49.73
MgO	-
SO <sub>3</sub>	1.10
K <sub>2</sub> O	-
P <sub>2</sub> O <sub>5</sub>	-
TiO <sub>2</sub>	0.076
V <sub>2</sub> O <sub>5</sub>	0.01
Cr <sub>2</sub> O <sub>5</sub>	0.01
Cu O	0.929
ZnO	0.30
BaO	0.12
Y <sub>2</sub> O <sub>3</sub>	0.78
H <sub>2</sub> O <sup>+</sup>	44.74

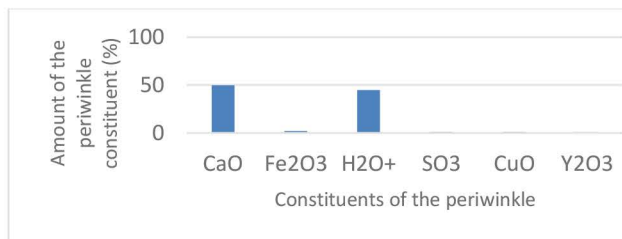


Fig. 1. Chemical Composition of Periwinkle shell ash

### Physical and Mechanical Properties of Composites

The properties such as density, water absorption, thickness swelling, and modulus of rupture, modulus of elasticity, young modulus, percentage elongation and Ultimate tensile strength are presented in this section. The density of the composite of various composition is shown in Table 3 and Fig. 2.

Table 3: Density of Periwinkle shell ash plastic composite of various compositions

Mass of Periwinkle shell ash in the composite (g)	5	10	15	20
D (g/cm <sup>3</sup> )	0.45	0.46	0.47	0.51

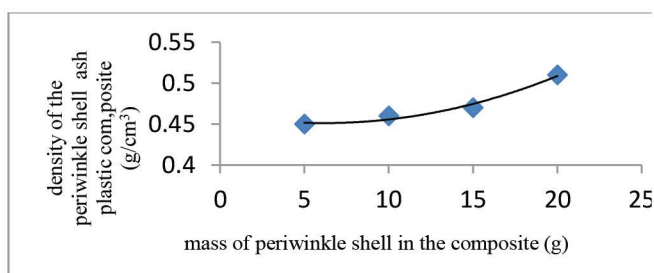


Fig.2. Density of Periwinkle shell ash composite vs mass of periwinkle shell (g)

### Water Absorption and Thickness Swelling of the composite

The results of the water absorption and thickness swelling tests of the composite of various compositions are presented in Table 4 and Fig.3.

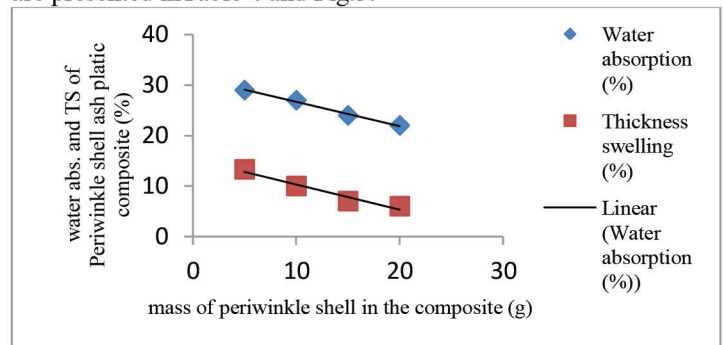


Fig.3: Water absorption and Thickness Swelling vs mass of Periwinkle shell (g)

Table 4: Water absorption and thickness swelling of the Periwinkle shell ash plastic composite of various compositions

Mass of Periwinkle shell ash in the composite (g)	5	10	15	20
Water absorption (%)	29.00	27.00	24.00	22.00
Thickness swelling (%)	13.30	10.00	7.00	6.00

### Bending strength

The load (N) and extension (mm) were obtained for each test conducted, while Modulus of Rupture and Modulus of Elasticity were calculated (Table 5) and Fig. 4.

Table 5: Modulus of rupture (MOR) and modulus of elasticity (MOE) of Periwinkle shell ash plastic composite of various compositions.

Mass of Periwinkle shell ash in the composite (g)	5	10	15	20
Modulus of rupture (MPa)	18.42	25.80	23.08	17.34
Modulus of Elasticity (MPa)	41.52	98.81	108.81	48.44

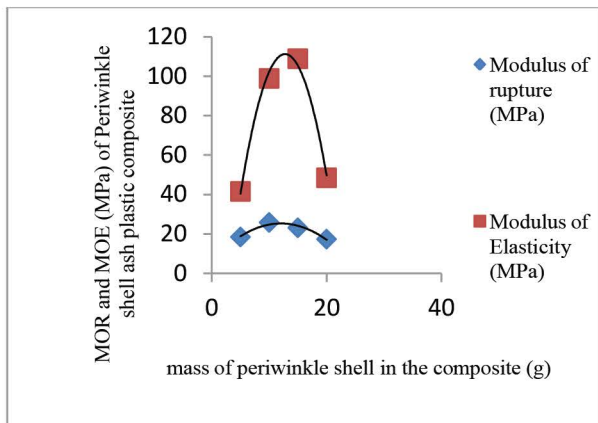


Fig.4. Modulus of rupture (MOR) and Modulus of elasticity (MOE) of periwinkle shell plastic composite vs mass of Periwinkle shell (g)

Ultimate Tensile strength (UTS), Percentage elongation and Young Modulus (E)

The load (N) and extension (mm) were obtained for each test, while ultimate tensile strength, tensile modulus, and percentage elongation were calculated (Table 6) and Fig. 5.

Table 6: Ultimate tensile strength, percentage elongation and young modulus (E) periwinkle shell ash plastic composite of various compositions.

Mass of Periwinkle shell ash in the composite (g)	5	10	15	20
Ultimate tensile strength (MPa)	7.39	9.32	8.27	7.73
Tensile modulus (MPa)	17.70	25.90	15.86	12.20
Percentage elongation	41.75	36.00	52.17	63.39

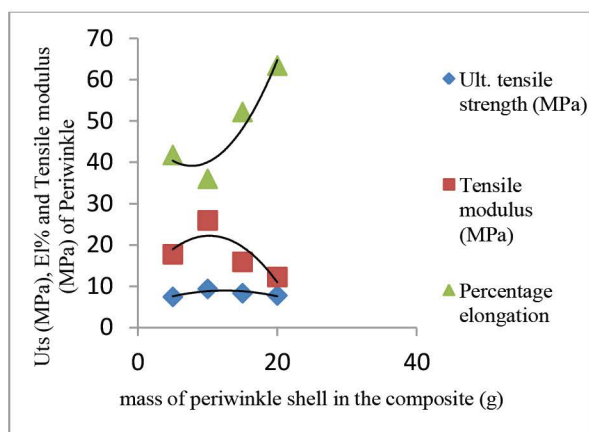


Fig.5. Ultimate tensile strength (UTS), Tensile Modulus (E) and Percentage elongation (%El) vs mass of Periwinkle shell (g).

## B. Discussion

### Chemical composition of Periwinkle Shell

Figure 1 showed that calcium oxide (CaO) has the highest percentage in periwinkle shell. The presence of CaO in the periwinkle is an important ingredient that provides strength to the periwinkle which makes it like cement. The presence of silica in periwinkle indicates a pozzolan material. Pozzolans contain a reactive silica and / or alumina which on their own have little or no binding property but when mixed with lime in the presence of water, will set and be hard like cement. Silica has an important property such as high thermal insulation and low bulk density in which makes it good in particle board production and more advantageously, has a low weight when considering the cost of transportation.

### Bending/Flexural test Results

From the results obtained from the tests conducted, the average values of stiffness strength (MOR) of the periwinkle shell ash plastic composite ranged from 25.80 - 17.33 MPa. The modulus of elasticity (MOE) average values of the periwinkle shell plastic composite ranged from 41.52 - 108.80 MPa. From these results, it can be inferred that the modulus of rupture of the plastic composite increased up to 10 % wt. and then decrease with further addition in the weight, and that modulus of elasticity increased up to 15% wt with decreased as the increased which of course, indicated that the particles are properly coated at 10-15% wt with little or not touching each other.

The MOR ranged from 25.80 - 17.33 MPa (Fig. 4) this has thus satisfied MOR requirements of 11.5 MPa for general purpose boards by EN 312-2 (1996).

### Ultimate tensile strength, tensile modulus and Percentage Elongation of the composite

From the results obtained from the test conducted, the average values of ultimate tensile strength of the periwinkle shell ash plastic composite ranged from 9.32 - 7.39 MPa. The average values of Tensile Modulus of the periwinkle shell ash plastic composite developed ranged from 25.90 - 12.21 MPa. The percentage elongation of the periwinkle shell ash plastic composite developed ranged from 63.39 - 36.00 %. From the results, the ultimate tensile strength of the periwinkle shell ash plastic composite and the tensile modulus of the plastic composite increased up to 10 % wt. with decreased with further increased in the weight of the reinforcement. However, the percentage elongation increased inconsistently as the weight increased. However, the percentage elongation of the composite decreased along as the weight increased.

### Density, water absorption and thickness swelling of the Composites

The average density of the periwinkle shell ash plastic composite ranged from 0.45-0.51 g/cm<sup>3</sup> The average water absorption and thickness swelling of the periwinkle shell ash plastic composite ranged from 29 - 22 % and 13.3 - 6 % respectively. From the results, the density increased as the mass of the reinforcement increase in the composite.

#### IV. CONCLUSION

The use of periwinkle shell particles as reinforcement in polythene matrix brings about improvement in the physical and mechanical properties. The assessment of the properties of the periwinkle shell – plastic composite showed that reinforcement yielded several promising results. These are:

- i. There is enhancement in the mechanical properties of the polythene composites up to 10%wt periwinkle shell loading.
- ii. Periwinkle shell particulate fibre in the range 5-10%wt gave the optimum results which show that low fibre weight content is good for better enhancement of properties.
- iii. The physical properties of the periwinkle shell composite such as density increased as the loading of the periwinkle shell particles increased. However, the water absorption of the composite decreased along the loading.

The composite could be used to produce particle board since MOR ranged from 25.80 - 17.33 MPa (Fig. 4) and thus satisfied MOR requirements of 11.5 MPa for general purpose boards by EN 312-2 (1996).

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